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# *Future Fuels*

## Flag Officers & Senior Executive Service

4 October 2005  
The Pentagon Auditorium

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# Terms of Reference

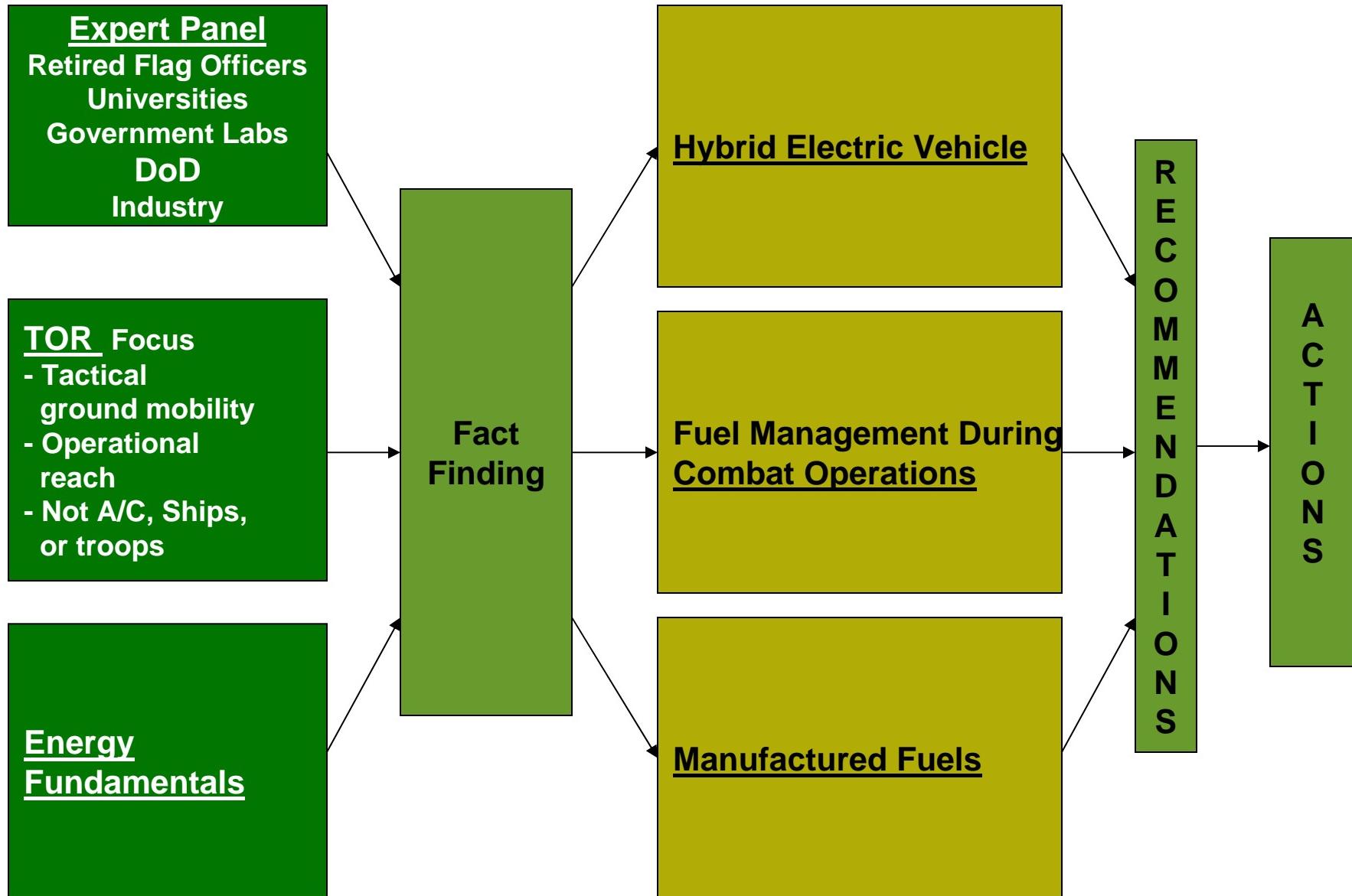
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- ***Focus on tactical ground mobility and increasing operational reach***
- ***Identify, review, and assess***
  - ***Technologies for reducing fuel consumption, including alternative propulsion technologies***
  - ***Militarily useful alternative fuels***
- ***Recommend a strategy to leverage the cooperative research among DoD, DoE, and industry***

***“Unleash us from the tether of fuel.”***

***-LtGen James Mattis, USMC***

# Study Flow



# **Fact-Finding**

## *Briefings from...*

### Service Perspectives

MCCDC, HQMC  
DASN (RDT&E), ONR, NRL  
HQDA (S&T), TARDEC, Army PM (Unit of Action)  
USAF AFRL



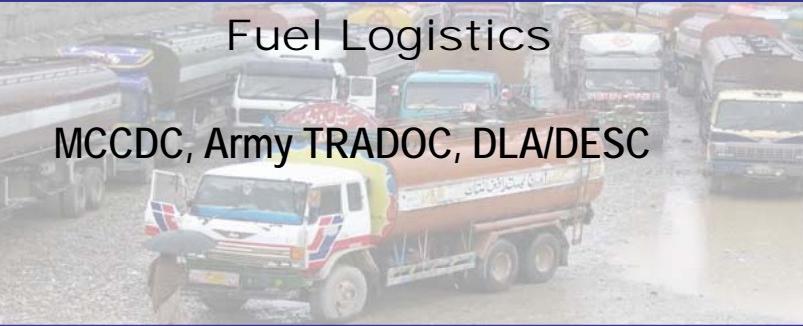
### Energy & Emissions Policy

DoE, OSD, OPNAV N42



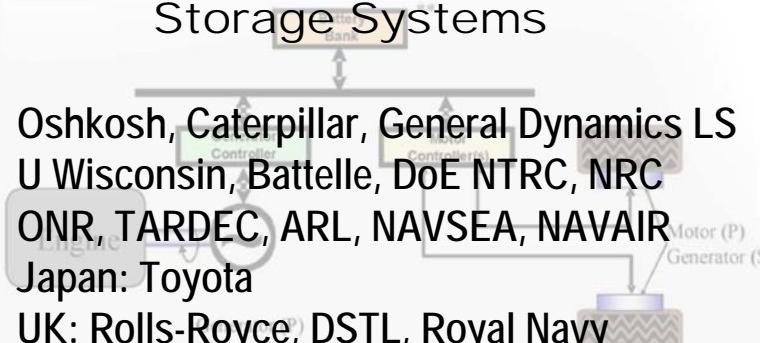
### Fuel Logistics

MCCDC, Army TRADOC, DLA/DESC



### Propulsion & Energy Storage Systems

Oshkosh, Caterpillar, General Dynamics LS  
U Wisconsin, Battelle, DOE NTRC, NRC  
ONR, TARDEC, ARL, NAVSEA, NAVAIR  
Japan: Toyota  
UK: Rolls-Royce, DSTL, Royal Navy



### Alternative Fuels & Fuel Manufacturing

DoE HQ, Oak Ridge National Laboratory  
OSD, DARPA, ONR, NRL, NSWC  
Shell Oil, Baard Generation, Rentech



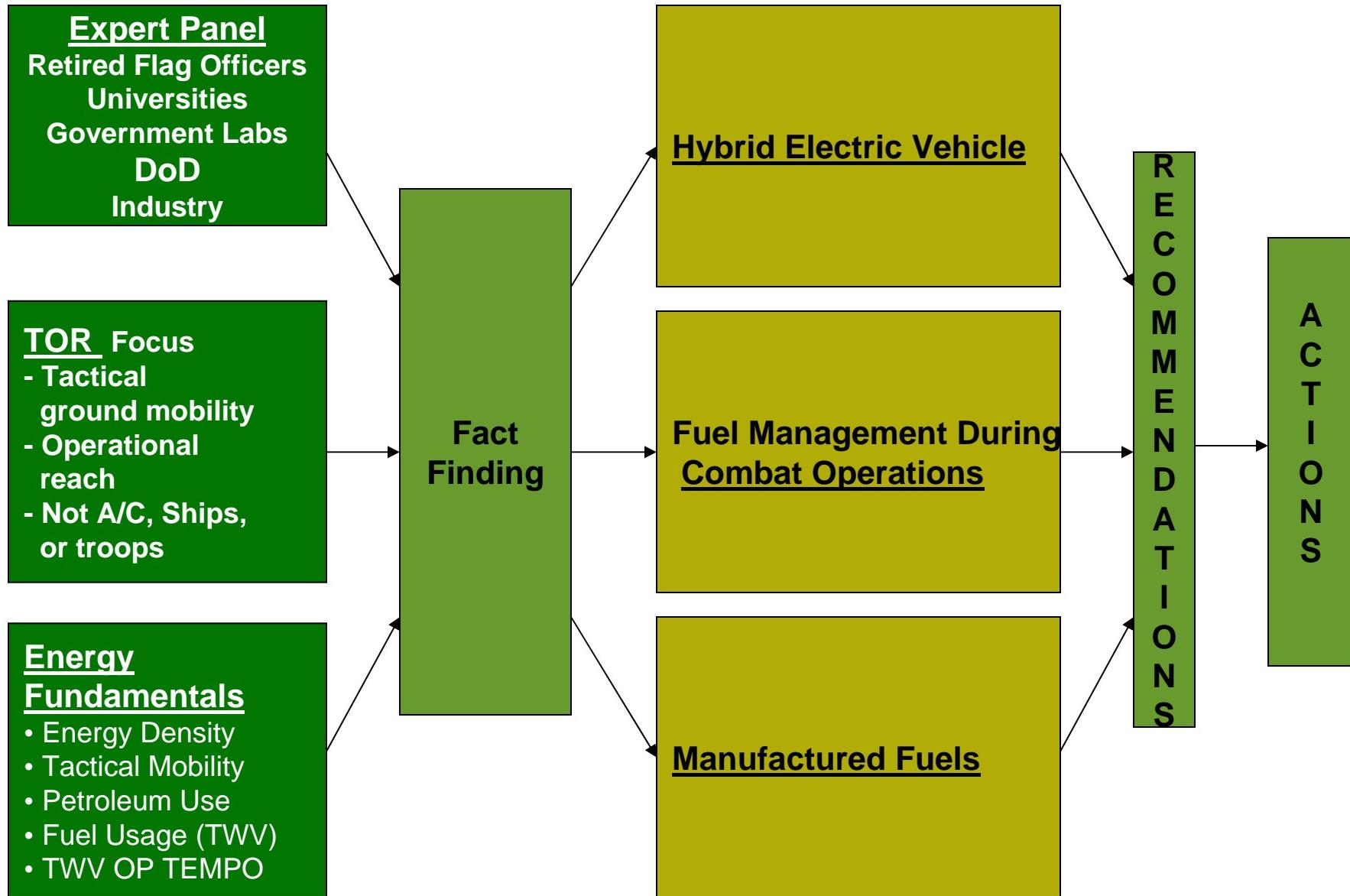


## Takeaways

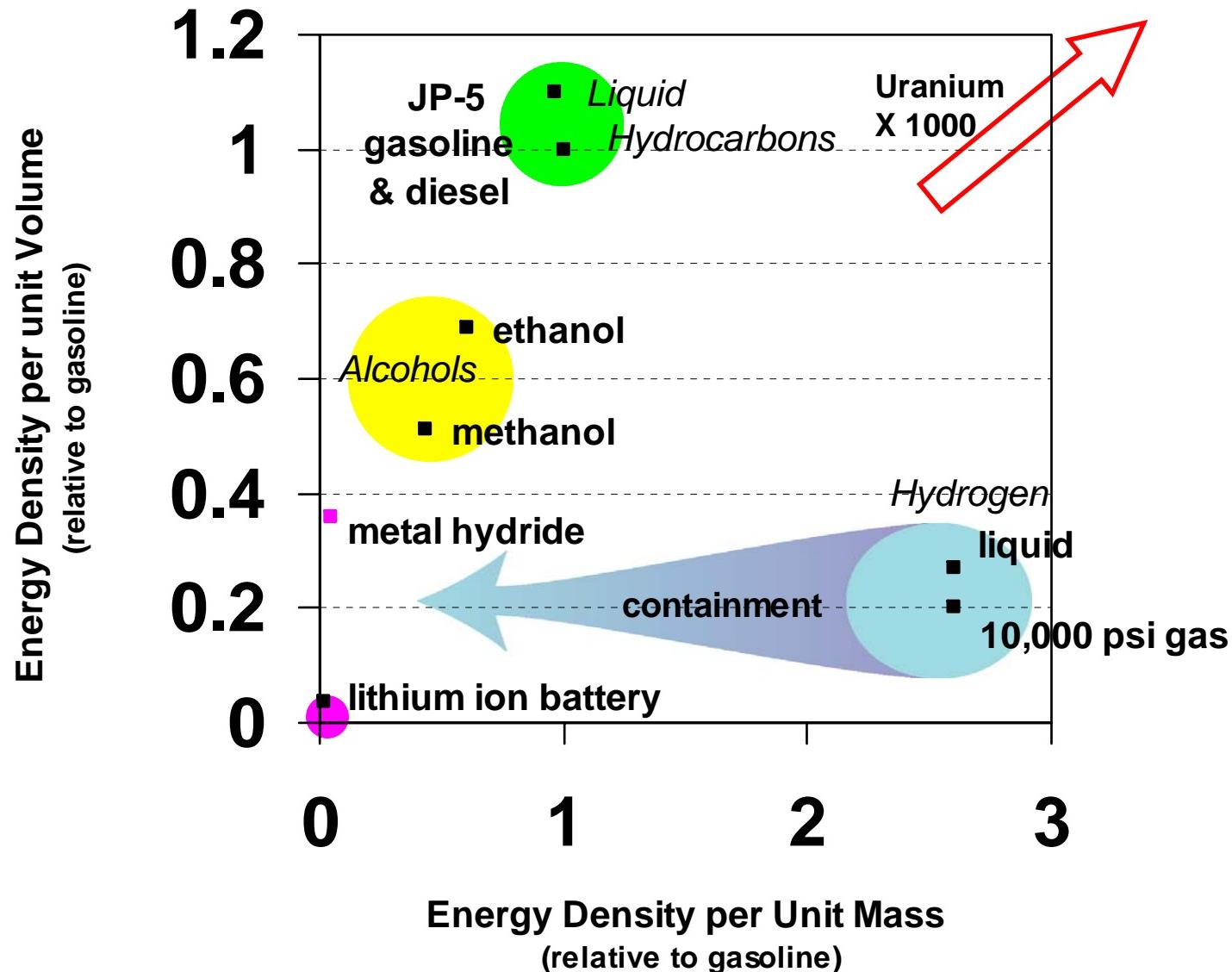
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- *Fuel Economy is Combat Power ...  
a key performance parameter*
- *Liquid hydrocarbons ...  
the ideal transportation fuel*
- *No single “silver bullet” to 50% reduction in fuel consumption*
- *Key actions:*
  - *Commit to hybrid electric architecture for Tactical Wheeled Vehicles (TWV)*
  - *Long term commitment to manufactured liquid hydrocarbon fuels from domestically abundant feedstocks*

# Study Flow



# Energy Density of Fuels





# Tactical Mobility Fuel

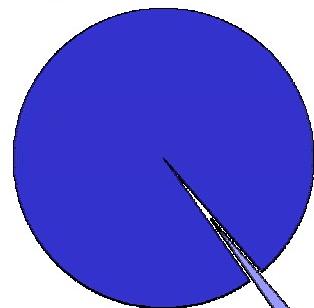
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- *Tactical Vehicle designs impose severe limitations on volume and weight*
- *Energy Density is therefore the primary figure of merit for transportation fuels*
- *Hydrogen presently unsuitable for a tactical mobility fuel*
  - *made using other fuels*
  - *containment reduces energy density a factor of 10 to 20*

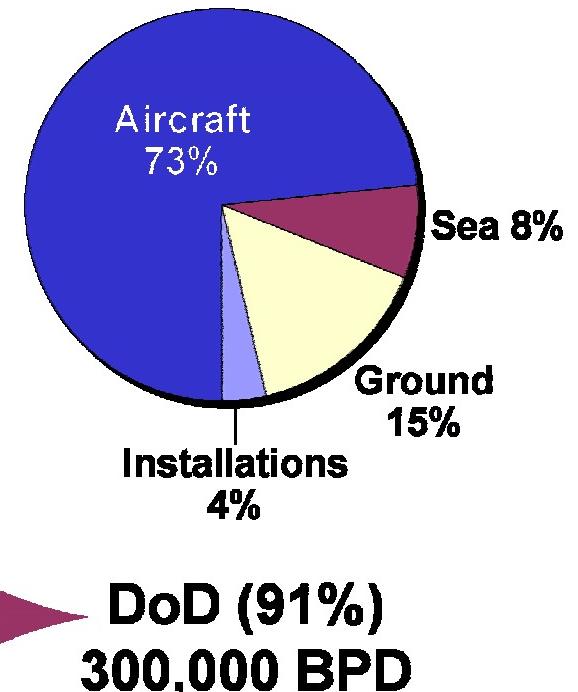
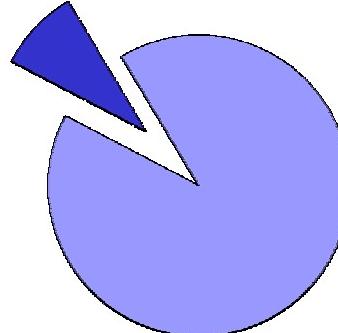
**Liquid Hydrocarbons are the ideal fuel for tactical mobility**

# Petroleum Usage 2003

National  
16,000,000 BPD

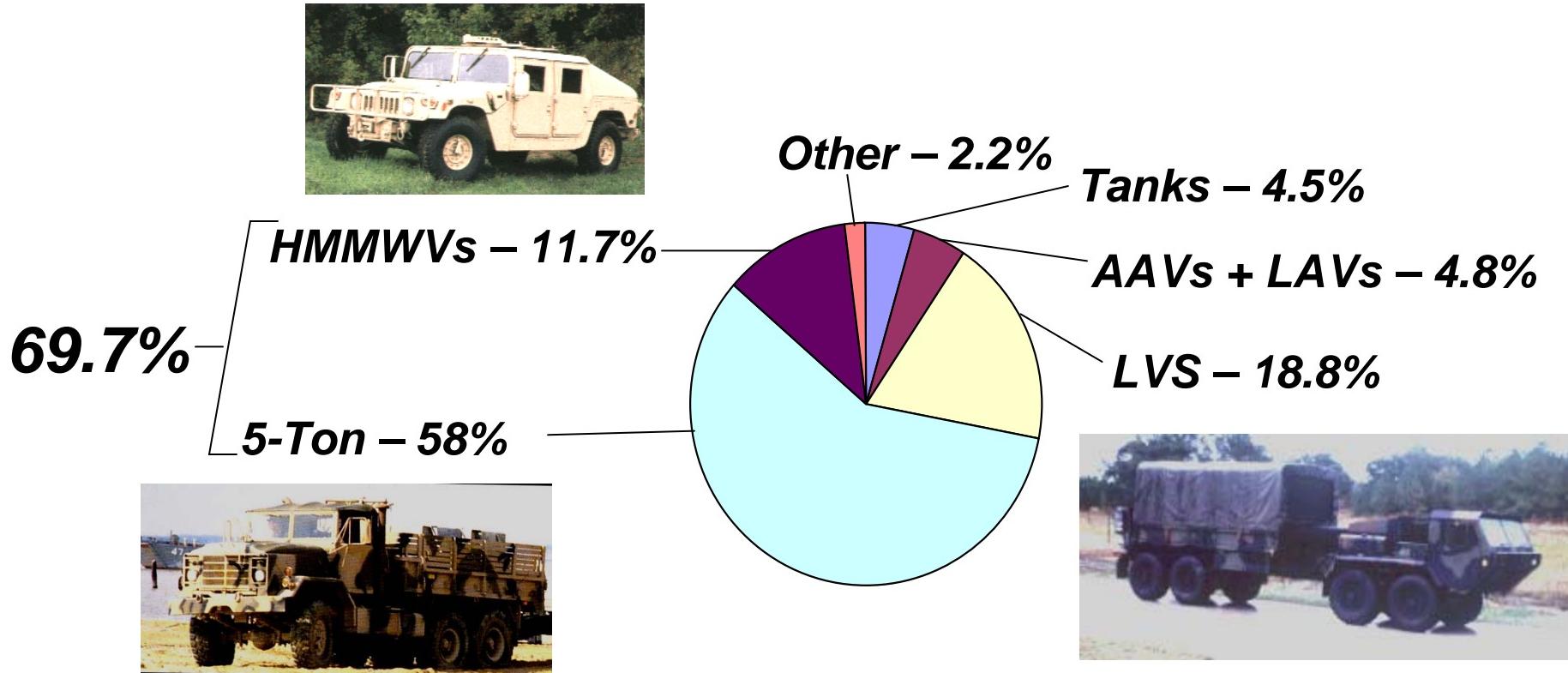


Federal Gov't (2%)  
330,000 BPD



**DoD Is Petroleum-Dependent ...But Cannot Drive The Market**

# Fuel Usage Tactical Wheeled Vehicles (TWV)



**Tactical Wheeled Vehicles Account for 88.5% of Fuel Usage**



## ***TWV Operational Tempo and Mission Profile***

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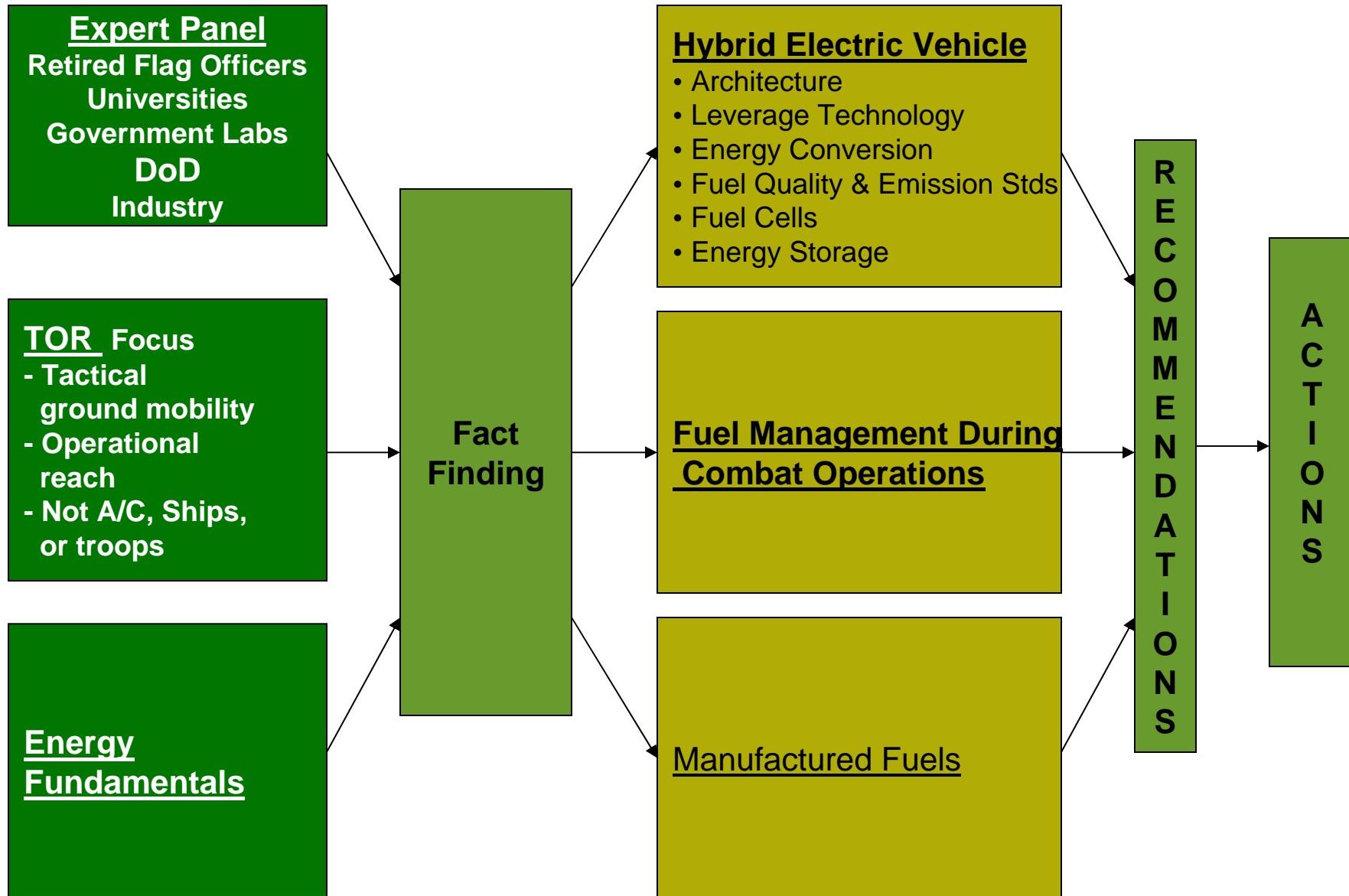
- ***May 2005 IGMC Findings from OIF:***
  - “*The fleeting nature of insurgents demands highly responsive, highly maneuverable and highly agile ground combat power*”
  - *All classes of TWV’s average 70-75% off road/unimproved roads*
  - *Heavy reliance on Mobile Electric Power (MEP) throughout the AOR*
- ***Distributed Op’s further complicate TWV power & fuel***
- ***Electrical power requirements growing rapidly***

**Future TWV’s...off-road fuel efficient with power generation**

## ***Future battlefield mobility requires effective utilization of fuel***

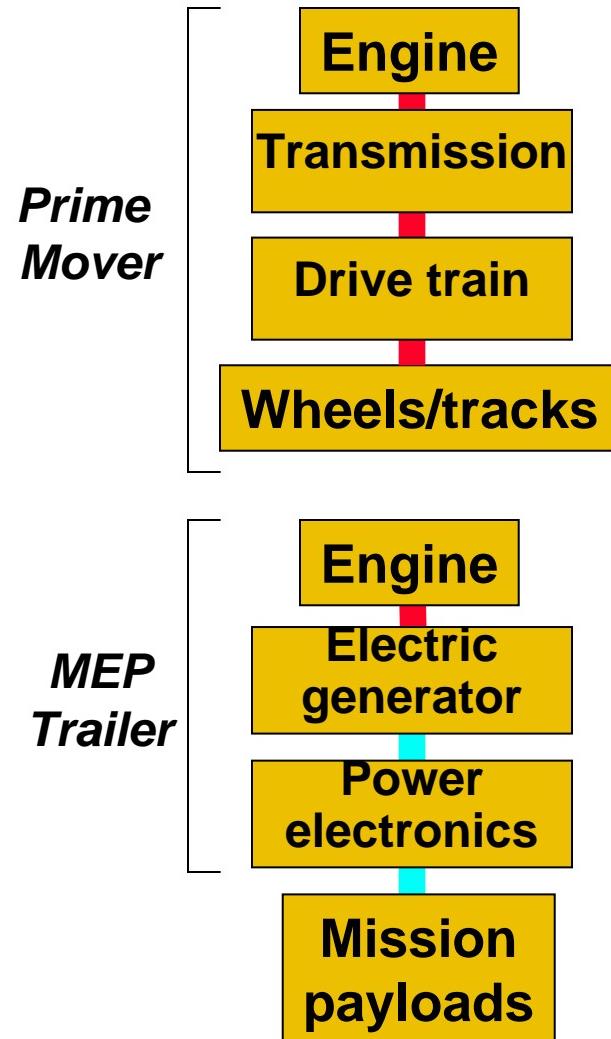
- ***Nearer-term payoff (PR 07/POM 08)***
  - ***Vehicle architecture implementation***
  - ***Commander's fuel management***
- ***Longer-term payoff (2015 & beyond)***
  - ***Fuel manufacturing***

# Study Flow

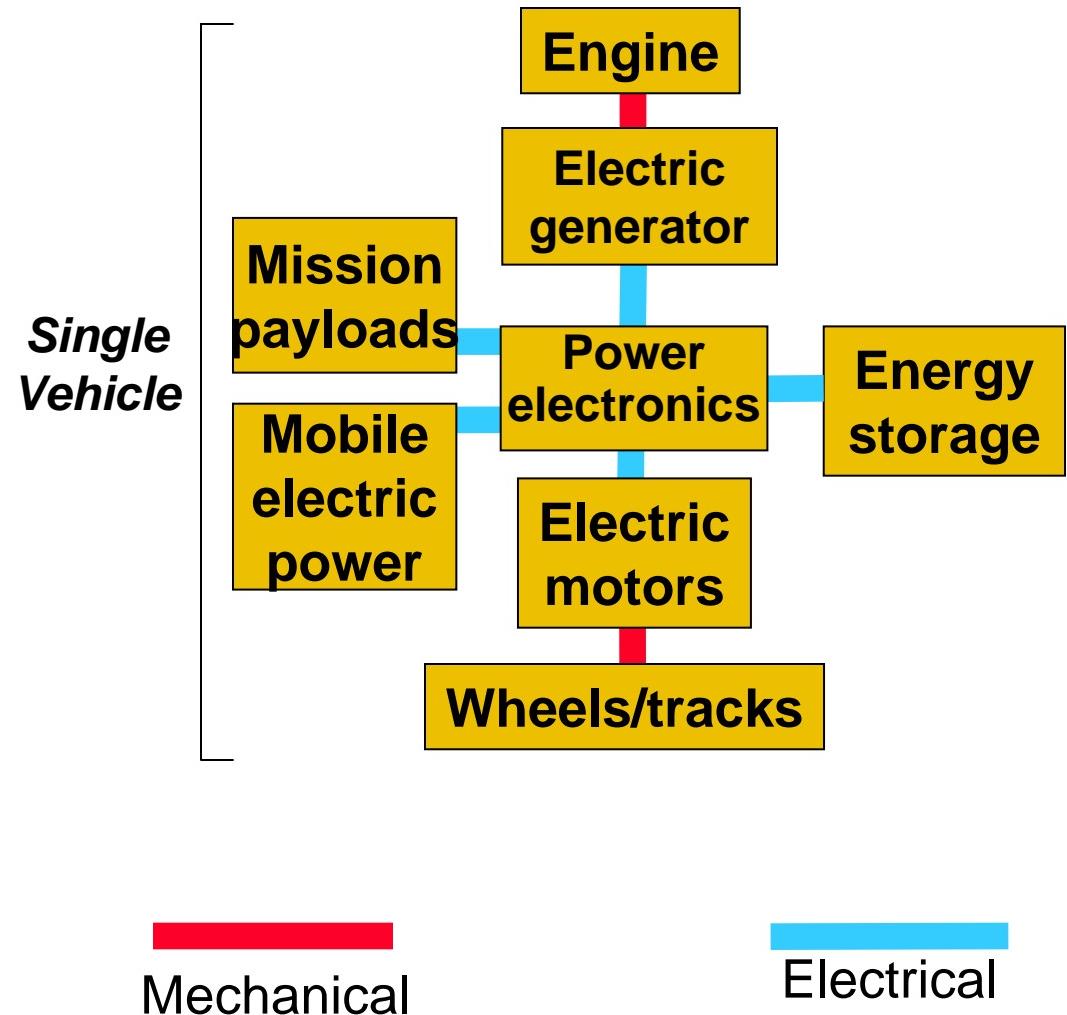


# Comparison of Vehicle Architectures

## All Mechanical



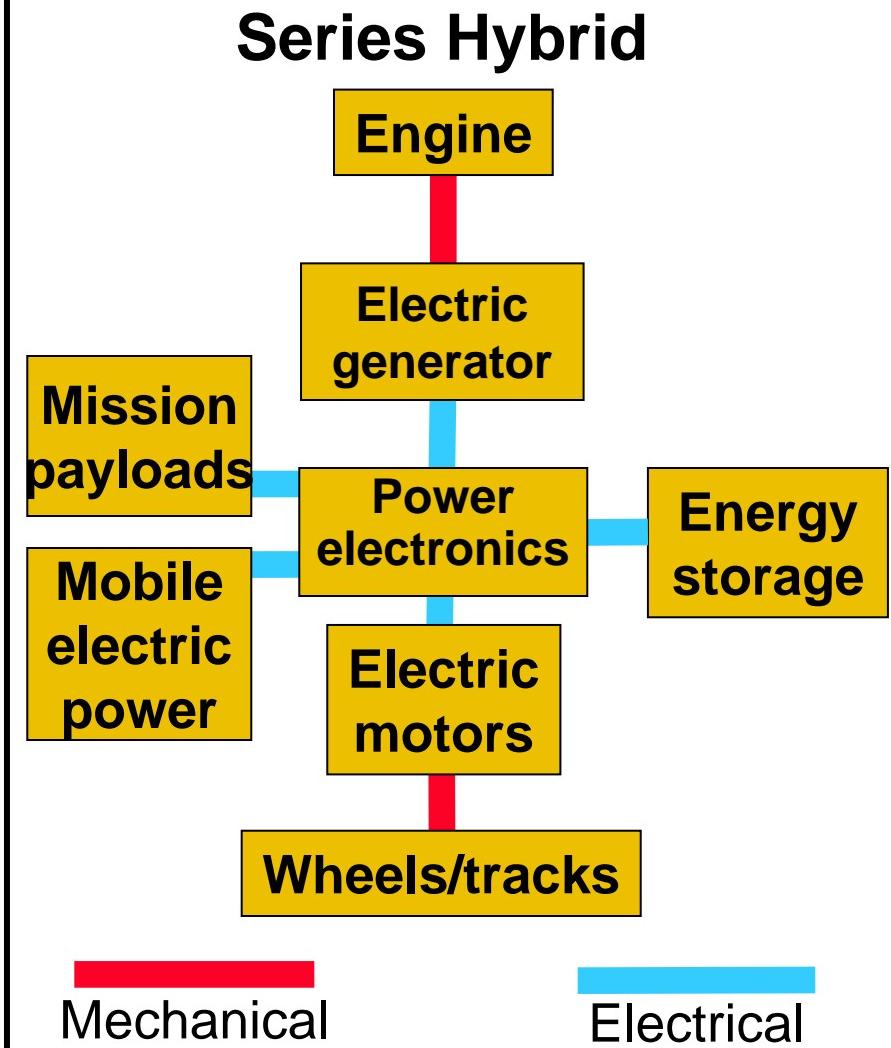
## Series Hybrid Electric



Mechanical

Electrical

- **Vehicle design flexibility**
- **Power distribution flexibility**
  - *traction power*
  - *mission payloads*
  - *mobile electric power*
- **Improved survivability**
- **Inherent modularity**  
*improves maintainability & upgradability (readiness)*
- **Design growth to emerging electric sources (e.g. fuel cells)**





# Opportunities to Leverage Technology

## Hybrid Electric Vehicles

Technology/Action	Commercial	Army	Needed (Naval)	
			Fund	Adapt
<i>Systems Engineering</i>	●	●	●	
<i>Power Electronics and Controls</i>				
– <i>Size</i>		●		●
– <i>Thermal Management</i>		●		●
<i>Energy Storage</i>				
– <i>Batteries</i>	●	●		●
– <i>Ultra-Capacitors</i>	●	●		●
– <i>Flywheels</i>		●		●
<i>Energy Conversion</i>				
– <i>Engines</i>	●			●
– <i>Fuel Cells</i>	●			●
– <i>Reformers and Desulfurization</i>		●		●
<i>Motors</i>				
– <i>Permanent Magnet</i>		●		●
– <i>Wound Rotor</i>	●		●	
<i>Series Architectures and Integration</i>				
– <i>Modeling and Simulation</i>		●		●
<i>Active Heavy-duty Suspensions</i>		●	●	
<i>Integration of Mission Systems</i>				
– <i>Weapons and Armors</i>		●	●	
– <i>Pulse Power Technology</i>		●		●
<i>Mobile Electric Power</i>		●	●	
<i>RST-V Demonstration</i>			●	

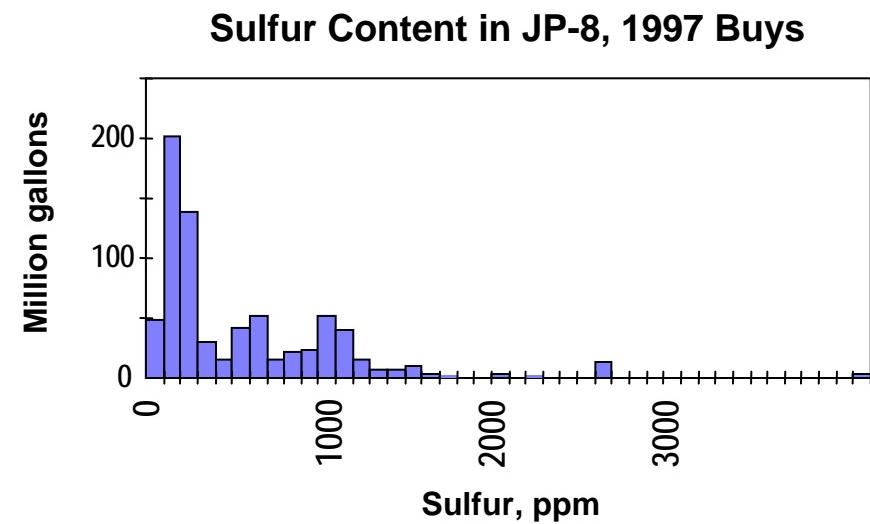
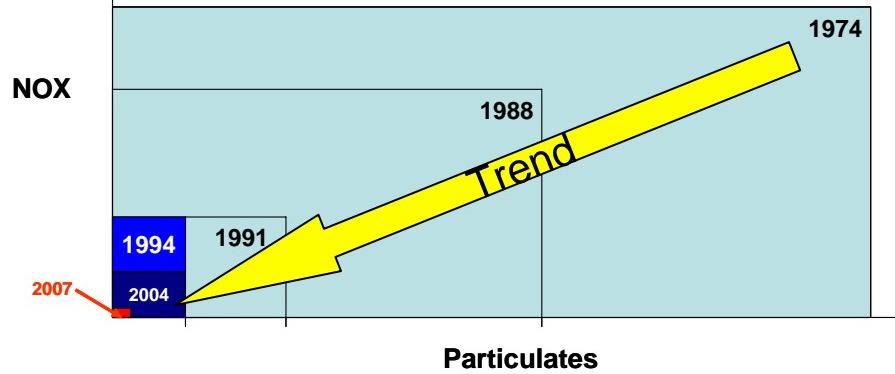


## ***Energy Conversion Diesel Engines***

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- ***Most fuel efficient***
- ***Commercial engines (or derivatives) offer the most affordable choice***
- ***But... commercial sector emphasis on emissions reduction leads to problems by 2010***
  - ***Performance and RAM-D sensitivity to substandard fuels***
  - ***After-treatment emission control systems cause significant vehicle integration and signature issues***
  - ***Increased importance of emissions waiver***

- **2010 Emission Standards -- Drastic Impact on DOD Tactical Vehicles**
  - After-treatment system as large as engine
  - Cooling system 30% larger
  - Cannot use substandard fuels without technological fix



**EPA Emission Waivers Need Support**



# Fuel Cells

## Long Term Alternative to Engines?

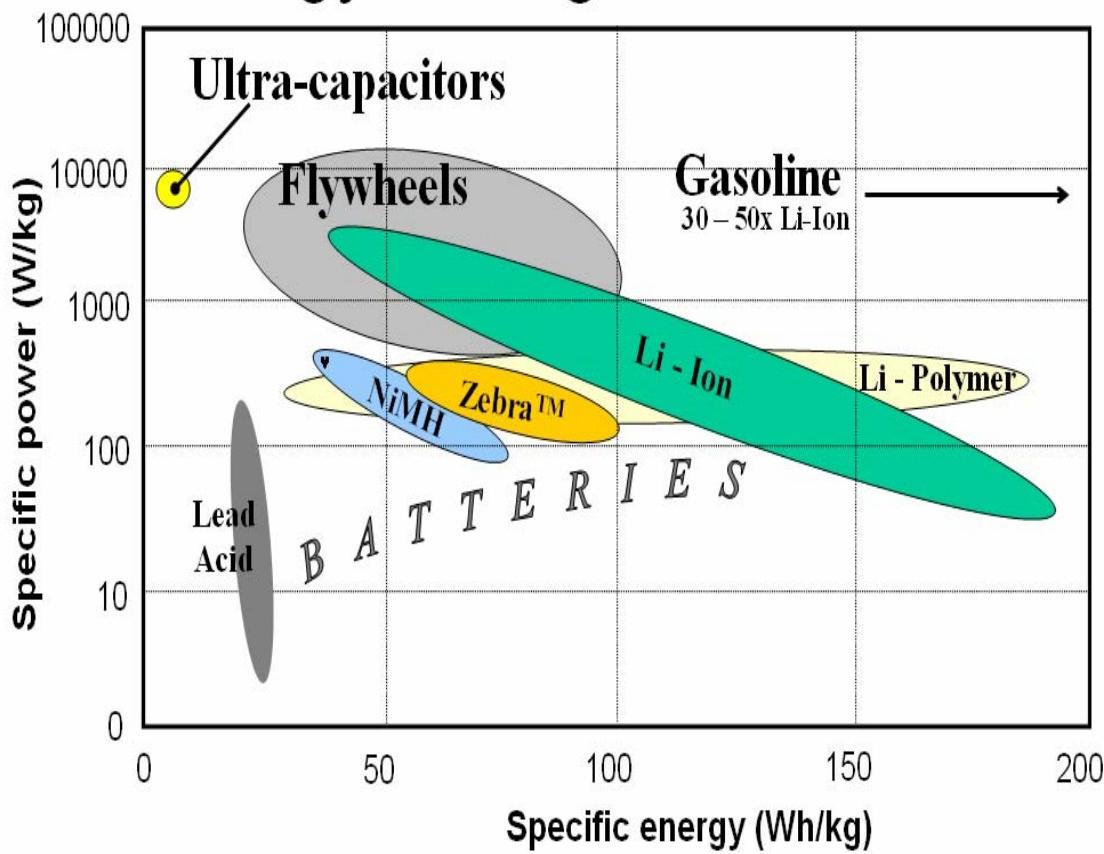
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- **Potential benefits**
  - *Efficiency*
  - *Pollution free, low signature*
  - *Electric power availability*
- **Commercial sector**
  - *primary source of technology for vehicle applications*
  - *focused on hydrogen fuel*
- **Military use: diesel fuel reformer / desulfurizer development critical**
- **Technical challenges include:**
  - *power density*
  - *cost*
  - *low temperature operation*
  - *start-up time, throttle response*
  - *durability*

**Not required for hybrid electric vehicles**

# Energy Storage

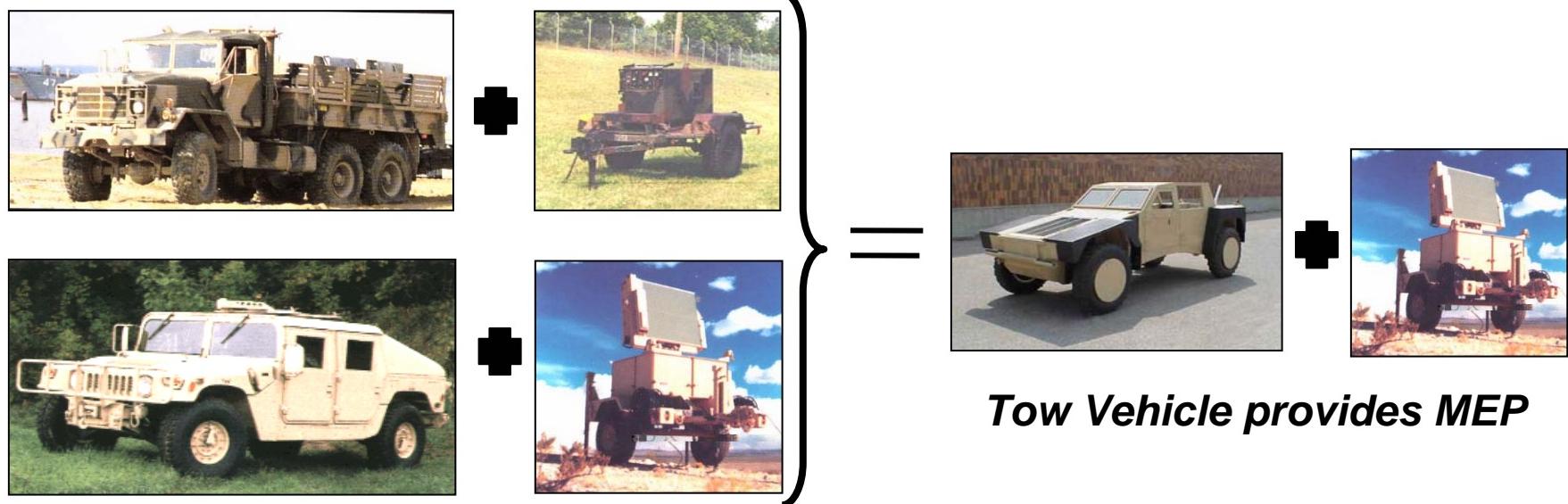
## Energy Storage Devices



- **Increases fuel efficiency**
  - Reduces engine power requirement
  - Regenerative braking
- **Challenges:**
  - Energy density
  - Cost
  - Durability
  - Safety
- **DoE and industry: Lead**
- **DoN: Stay informed**

## Benefits of HEV

- *20% improvement in fuel economy can significantly reduce existing MEF transportation shortfall*
  - Up to 56K gal per day (12+ trucks @ 4,500 gals/ea )
- *HEV electrical power reduces expeditionary footprint*



**HEV Technology for TWV Replacements Can Improve  
Fuel Economy and Enhance Operational Capability**

## Conclusion: Hybrid Electric Vehicle Architecture



*GDLS/USMC/DARPA  
RST-V Program:  
Complete*  
• 4 Prototypes in test  
• 2 in OIF JAN 06



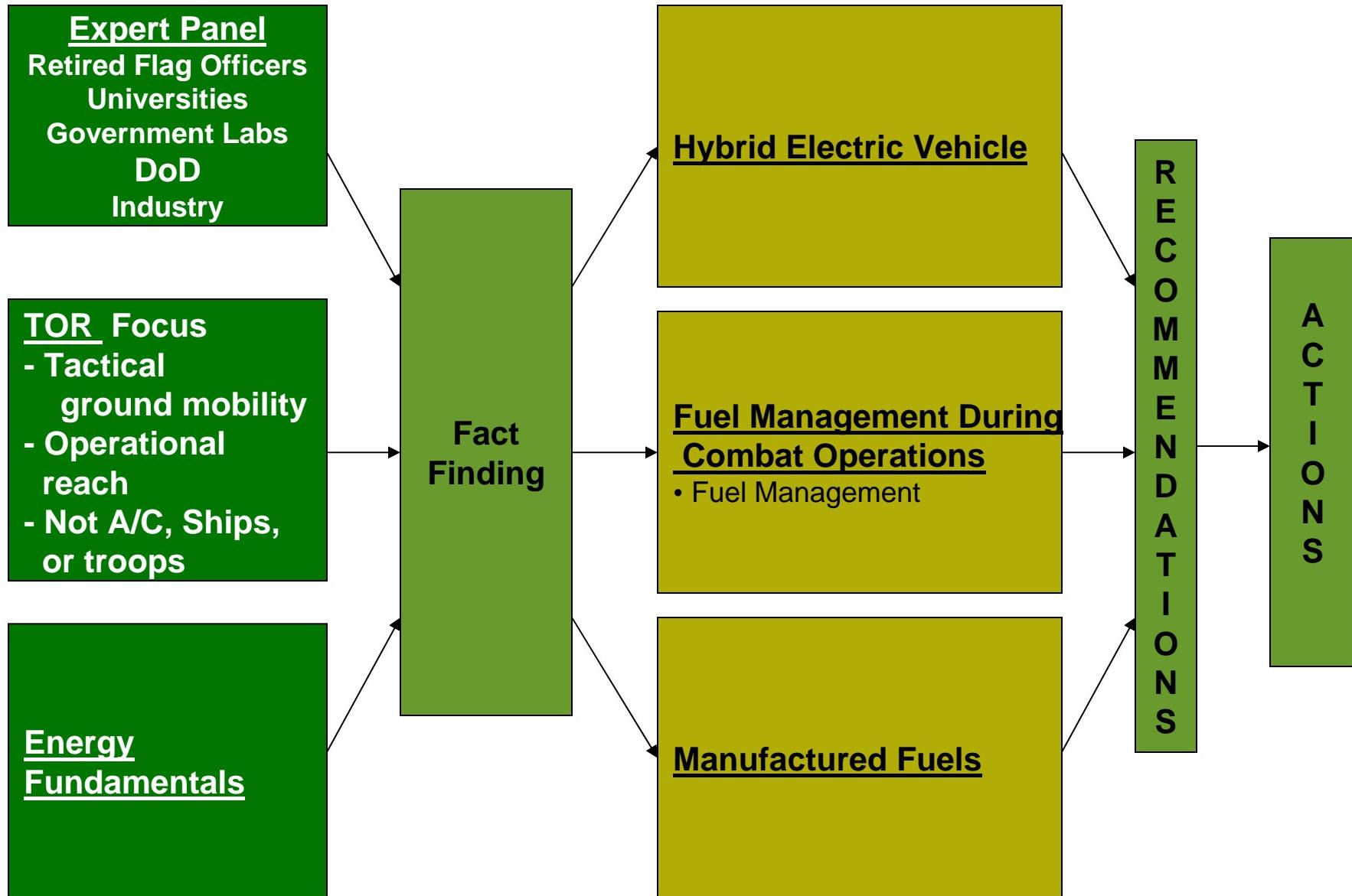
*GDLS/Army: Advanced  
Hybrid Electric Drive  
(AHED)*  
• One demonstrator  
• 19t



*Oshkosh/Army: HEMTT A3*  
• 20% better fuel economy  
• C130 interface  
• Exportable AC power

- **Demonstrated Mission Profiles - - -**
  - **Traction Control for Maneuverability / Agility**
  - **On/Off Road**
  - **Overt/Covert**
  - **Mobile Electric Power**
- **Applicable to Unmanned Vehicles**
- **20 % - Improved Fuel Usage...but limited data**
- **Expanded Trade-offs - - Reach & Mobility versus Added Systems Capability**

# Study Flow





## *Fuel Management During Combat Operations*

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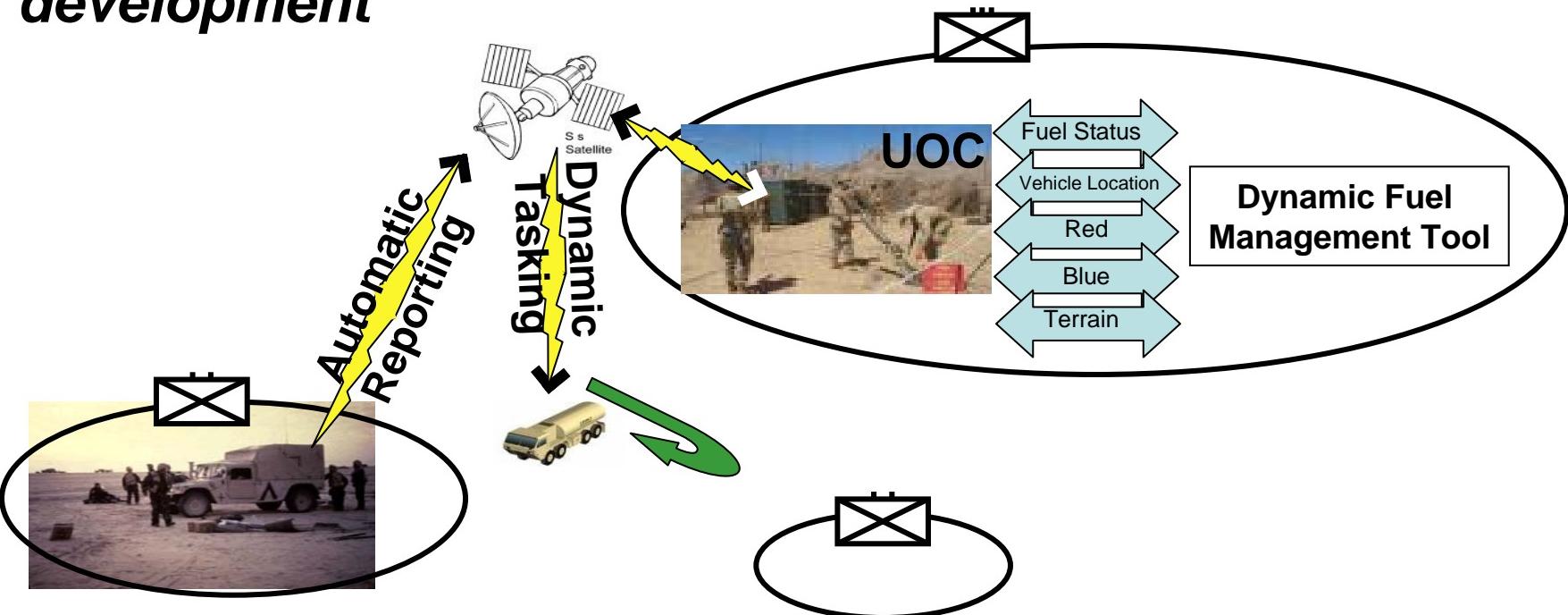
- *Improved fuel management increases operational reach*
- ***Comprehensive fuel visibility/dynamic allocation:***
  - *Conserves fuel and sustains op tempo*
  - *Reduces the number/vulnerability of fuel trains*
- ***Marine Corps' macro fuel estimating tool needs two additional critical elements***
  - *Automated vehicle fuel status and location reporting*
  - *Dynamic tasking via Blue/Red/Terrain data fusion*

***Fuel is not simply a commodity or logistics issue –  
it is an operational imperative***



# Conclusion: Fuel Management

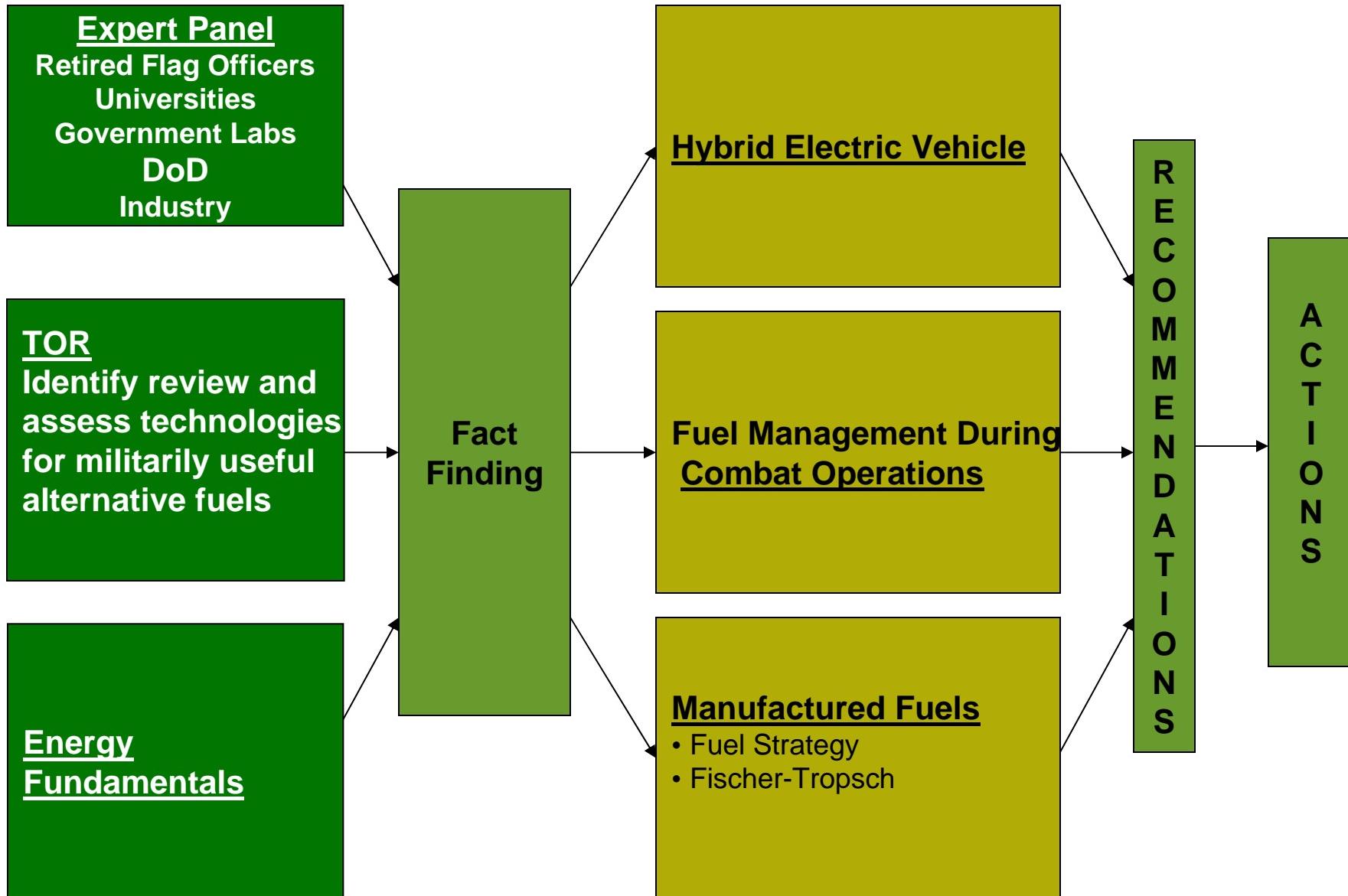
- *New tools to improve fuel management during combat operations*
- *Automatic vehicle location/fuel status reporting is the first step & is near term*
- *Dynamic allocation system requires substantial development*



## ***Future battlefield mobility requires effective utilization of fuel***

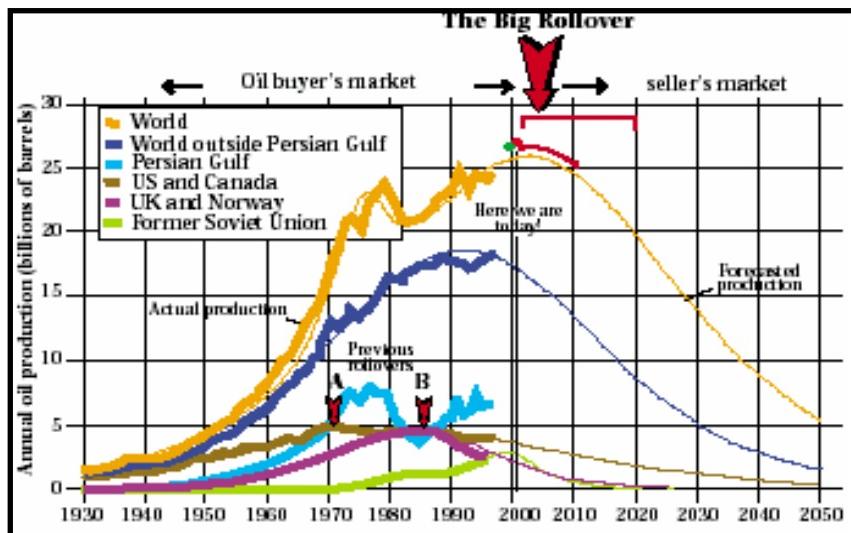
- ***Nearer-term payoff (PR 07/POM 08)***
  - *Vehicle architecture implementation*
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# Study Flow

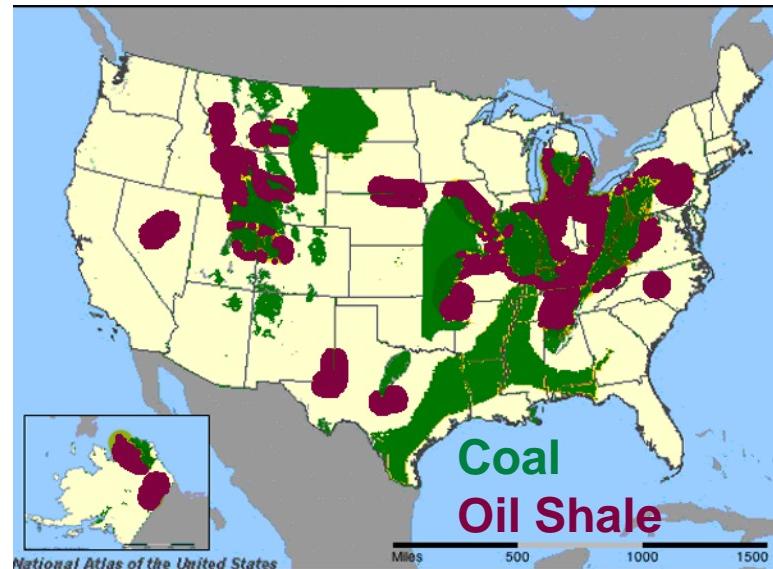


# Mid-to-Far Term Fuel Strategy

- Liquid hydrocarbon fuels have ideal properties and are needed as transportation fuels for the foreseeable future
  - Oil-derived fuels primarily imported and will become increasingly scarce
  - Existing refinery infrastructure
    - Predominantly coastal and vulnerable
    - Operating at capacity
- Alternative: Fuel efficiency, domestic resources, interior production

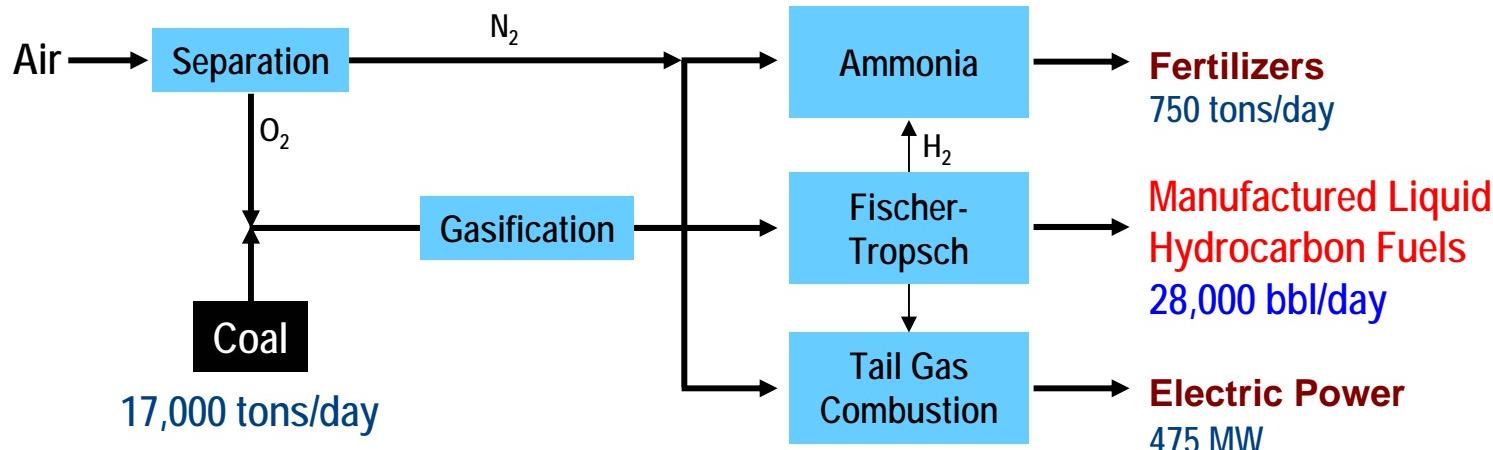


Median estimate of Hubbert's Peak  
based on 11 authoritative sources: 2010



# Manufacturing Fuel to Spec

- **Gasification + Fischer-Tropsch = Clean fuel from domestic sources**
- **Technology mature for natural gas, coal**
- **Significant development underway by South Africa, China, Gulf States**



Sasol Fischer-Tropsch Plant, Secunda, South Africa

- ~10 such plants would provide all DoD fuel
- Commercial financing of such plants viable, given DoD commitment to purchase manufactured fuels at attractive prices



## Conclusions: Manufactured Fuels

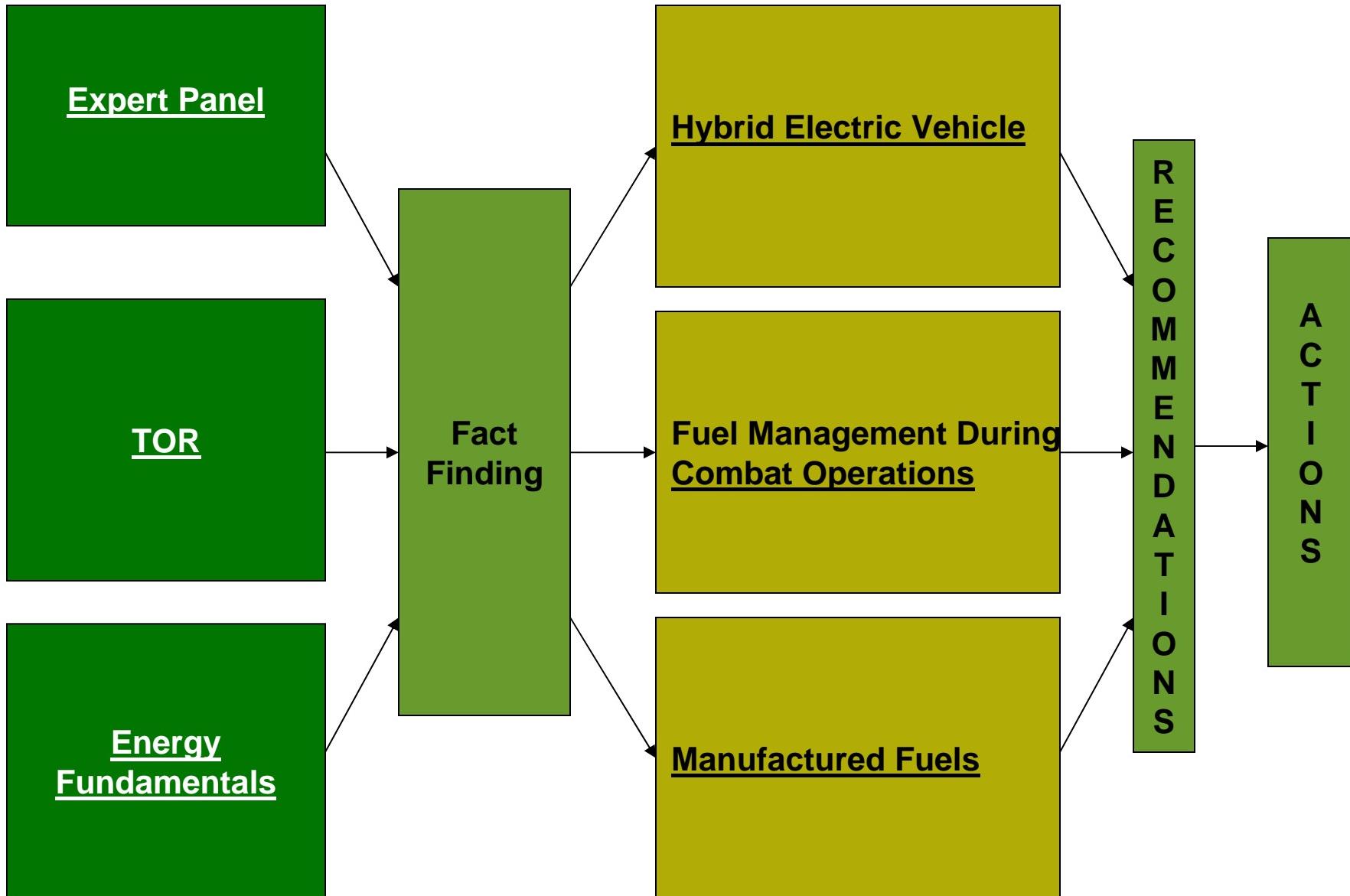
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- *Liquid hydrocarbon fuel production using domestic energy sources is feasible*
- *Commercial financing and infrastructure development will drive this process*
- *DoD action needed to catalyze development & ensure US military takes advantage of manufactured fuels*
- *Need to ensure military platforms can use manufactured fuels*

**Manufacture Fuel from Domestic Sources —  
Decrease Dependence on Imported Crude Oil**

# Study Flow

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# Recommendations

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## Nearer-term Payoff (PR 07/POM 08)

- ***Fuel tether is still there, but...***
  - *Found a way to lengthen it (HEVs)*
  - *And untangle it (Fuel Management)*
- ***Commit to HEV technology for all future TWV***
  - *Establish an HEV development roadmap*
  - *Immediately initiate system engineering trade-offs*
  - *Invest in on-going HEV development projects*
- ***Develop prototype system to enable real-time, in-stride fuel allocation for the Operational Commander***

## Longer-term Payoff (2015 & beyond)

- ***DoD catalyze manufactured liquid hydrocarbon fuels infrastructure***
- ***Characterize the compatibility of manufactured liquid hydrocarbon fuels with DoN equipment***



## ***Actions (1)***

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- ***Commandant of the Marine Corps (CMC)***
  - *Support application for emissions waiver submitted by Army*
- ***ASN (RDA)***
  - *With Services, advocate the use of multiyear procurement authority granted SECDEF in 2005 Energy Bill to catalyze commercial financing of large-scale FT plants producing transportation fuels*
- ***CG MCCDC (Request of CNR via CMC )***
  - *Establish new program elements (6.2 & 6.3) for HEV technologies*
  - *Demonstrate technologies for real-time fuel asset visibility*
  - *Develop real-time dynamic fuel allocation prototype system*
  - *Develop conditioning technologies for substandard tactical fuels*



## Actions (2)

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- **CNR: Support these CMC tech investment requests**
  - **Complete RST-V Technology Program**
    - Transition from DARPA to ONR for final maturation
    - Develop on-the-fly mission profile selection technology
    - Transition Mature Design to CG MARCORSYSCOM
  - **Complete On-Board Vehicle Power Program**
    - ONR Transition to CG MARCORSYSCOM
  - **Conduct real-time fuels status tech demos**
  - **Develop Commander's real-time dynamic fuel allocation prototype system**
    - Coordinate with DARPA to establish a joint program
  - **Develop technologies for conditioning expeditionary substandard tactical fuels**
  - **Monitor status of FT Plant authorized by 2005 Energy Bill**
    - Use fuel produced to conduct research on compatibility with current and future TWVs



***QUESTIONS?***



# Panel Membership

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